A Preliminary Vegetation Classification for the Colorado Plateau

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Abstract. A new vegetation classification is developed and applied to the Colorado Plateau. The Spence–Romme–Floyd-Hanna–Rowlands (SRFR) classification is loosely based on the Brown–Lowe–Pase system. The SRFR classification is hierarchical and open-ended and can be adapted to any region of North America. The levels in the hierarchy, from broad scale to fine scale, are biogeographic realm, floristic province, climate–elevation zone, plant formation, series, and association. A preliminary classification of the vegetation of the Colorado Plateau is presented to the series level.

Key words: Biome, climate zone, formation, plants, series.

We examine vegetation classification in the region of the Intermountain West known as the Colorado Plateau (Figure) as defined physiographically by

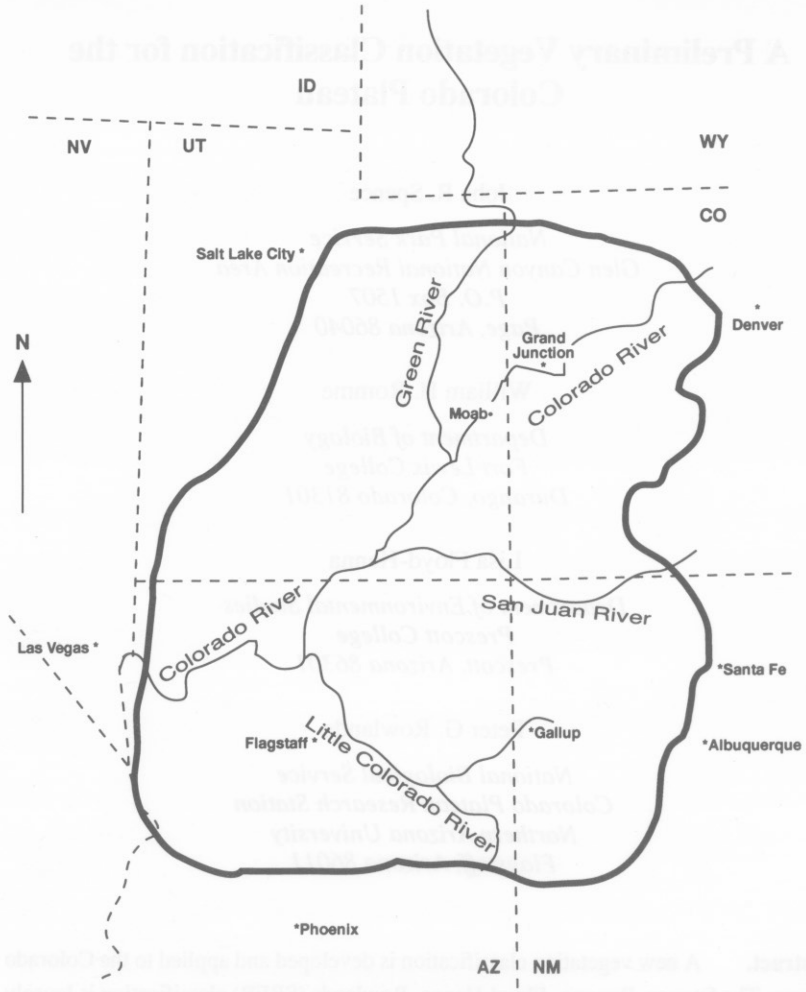

Figure. The Colorado Plateau physiographic province (after Hunt 1967).

Hunt (1967) and floristically by McLaughlin (1989). After a preliminary review of various classifications, some of which have been used or suggested for the region, we concentrate on a new vegetation classification based in part on the Brown–Lowe–Pase (BLP) classification (Brown et al. 1980). We provide a preliminary classification of the vegetation on the Colorado Plateau to the series level and present criteria and methods for classification of field data.

Literature Review

Classification of vegetation can be done at various scales of resolution. The detailed classifications of the U.S. Forest Service habitat and community types represent fine levels of resolution. Forest vegetation is classified by series and habitat–community types (associations) but is not incorporated into an explicit, higher-level classification. Above the level of series, several world and North American vegetation classifications have been applied, or could potentially be applied, to the Colorado Plateau. These include the classifications of Fosberg (1961), Holdrige (1967), Küchler (1964), UNESCO (United Nations Educational, Scientific, and Cultural Organization; 1973), and Brown et al. (1980; Brown 1982). Other, less widely used systems exist as well (Dansereau 1957; Krajina 1965). These classifications vary in the criteria used in their construction. Primary plant criteria include flora, physiognomy (structure), function, dynamics, and biogeography. Some are pure plant-based classifications, whereas others incorporate climate and elevation. Published work using at least three of the above criteria exist for portions of the Colorado Plateau–BLP (Brown et al. 1980), Holdrige (MacMahon and Wieboldt 1979; MacMahon 1988), and Küchler (1964; see also MacMahon 1988; West 1988).

The classification of Fosberg (1961) is simple, hierarchical, and predominantly plant-based. The main features used are dominant life-form (tree, shrub, herb, etc.) and density (spacing; e.g., open, closed). It is cumbersome because of the large numbers (31) of formations. Also, some of the differences between formations seem to be arbitrary (e.g., scrub savanna vs. low savanna).

The floristic classification of Küchler (1964) has been widely applied in the United States (Barbour and Major 1988; West 1988). The classification has many vegetation types (mapping units) and is nonhierarchical. Potential natural vegetation rather than actual vegetation is used. The primary criterion used is floristic (the dominant species present).

Holdrige (1967) developed a classification based on control of life zones by latitude, elevation, and climate. Each unique combination of biotemperature, precipitation, and evapotranspiration describes a particular life zone that is reflected in a particular kind of vegetation. The vegetation terms are largely structural–functional (i.e., steppe, desert scrub). Much climate information is needed to apply this system to a region. MacMahon and Wieboldt (1979; see also MacMahon 1988) have applied the classification to Utah.

The UNESCO system uses a hierarchical classification of primarily physiognomic features, within floristic provinces (UNESCO 1973; Mueller-Dombois and Ellenberg 1974). Forest, woodland, shrub land, and grassland are characteristic formations, with finer groupings detailed based on height, leaf size, and leaf duration. Fewer nonplant features are incorporated than with many systems. This classification is extensively used and is worldwide in scope. A modification of the UNESCO system was developed for use in the United States by Driscoll et al. (1984). Their classification differs from the original in the incorporation of the concept of potential natural vegetation (or climax vegetation), as in the classifications of Küchler and U.S. Forest Service.

The BLP system (Brown 1982) incorporates vegetation, flora, topography, and climate. It is the most explicitly hierarchical and open-ended of the systems detailed. Although used primarily in the western United States, the system may be adaptable to the world level, as noted in Brown et al. (1980). This system was the one chosen for use in National Park Service units on the Colorado Plateau (Spence 1993; Bennett and Kunzmann 1991*[1]). Spence (1992*) analyzed the structure of the BLP system with reference to the Colorado Plateau.

The BLP system as currently described is inadequate to classify the vegetation of the Colorado Plateau. In particular, several problems were encountered that required solutions before the classification could be applied to the Colorado Plateau. Below, we examine these problems within each of the levels in the BLP hierarchy and discuss our solutions.

Upland–Wetland

Vegetation exists across a continuum of moisture availability, and, although the endpoints may be distinct, any attempt to differentiate wetlands and uplands is arbitrary. Classifying vegetation into these categories is both unnecessary and redundant. The plants, especially at the formation and series levels, already reflect site differences in available moisture. The upland–wetland level is therefore dropped from our classification.

Formation

Formations are traditionally named after the physiognomy of the vegetation (e.g., forest, grassland, etc.). In the BLP system, however, logically unrelated concepts are mixed. Two formations are climate–landscape terms (tundra and desert land), whereas the rest are true plant structural formations (e.g., forest, grassland). This produces some problems in classification (e.g., grass-dominated vegetation could be classified under both grassland and tundra). We have removed tundra from the system because tundra vegetation can be classified as shrub land, grassland, or forb land.

[1]Asterisk indicates unpublished material.

The BLP formation desert land (sometimes called desert scrub) is redefined and named thorn scrub. Subtropical and tropical arid thorn scrub vegetation, consisting of drought deciduous thorny trees and large succulents, is different in origin, function, and structure from the simpler shrub lands and forests in the southwestern United States and Mexico (cf. Brown 1982).

We added two formations, tall and low-shrub lands, based on height and growth form of shrubs. Tall-shrub land is equivalent to scrub in the BLP system. Low-shrub land was necessary to classify some shrub vegetation on the Colorado Plateau. In the original BLP system, shrub vegetation was classified under either scrub (tall-shrub land) or desert land (desert scrub). Much low shrub vegetation on the Colorado Plateau and elsewhere in western North America, however, is neither scrub nor desert land.

To classify certain communities on the Colorado Plateau, a formation was needed that represented broad-leaved forbs, both annual and perennial. This vegetation included certain subalpine forb communities (very common in the central-northern Rockies) dominated by *Lupinus*, *Mertensia*, various Asteraceae, *Thalictrum*, etc., and in which grasses are generally unimportant. Also, some badland communities on heavy clays and shales are dominated by annual species of *Atriplex*, *Eriogonum*, and *Phacelia* (nomenclature follows Welsh et al. 1993). We added a forb land formation to the classification. Formations are defined below.

Forest and woodland—Vegetation dominated by trees (usually or potentially 10 m high). Forests have closed (interlocking or touching) canopies whereas woodlands have open canopies.

Thorn scrub (desert scrub or desert land of BLP in part)—Tropical–subtropical arid land formation dominated by a mix of microphyllous trees and shrubs, and tall succulents, often spiny or thorny (e.g., Sonoran Desert).

Savanna—Tropical–subtropical formation of grasses with an open canopy of widely spaced trees, dominated by tall seasonal grass layer. Savanna is not found on the Colorado Plateau.

Tall-shrub land (scrub of BLP)—Vegetation dominated by shrubs, mostly less than 5 m high, usually multistemmed, open (shrub land or scrub), or densely interlocked (thickets). Tall-shrub land is traditionally called scrub in many parts of the world.

Low-shrub land (desert scrub or desert land of BLP in part)—Vegetation dominated by woody, single, or multistemmed dwarf or mat shrubs that are generally less than 1 m high.

Grassland—Vegetation dominated by perennial or annual species of grasses.

Marshland—Vegetation dominated by herbaceous obligate wetland species of sedges, rushes, and cattails.

Forb land—Vegetation dominated by herbaceous perennial and annual species of broad-leaved dicots, ferns, or nongraminoid monocots (e.g., lilies, irises).

Aquatic—Vegetation dominated by herbaceous species that are supported by water and are either rooted with their structures underwater or floating on the surface or plants free-floating on the surface.

Cryptogamic—Vegetation dominated by cryptogams, either lichens or bryophytes (includes *Sphagnum* bogs).

Nival—Permanent snow and ice with some exposed rock, dominated by cryptogams, with vascular plants rare. Nival probably is not found on the Colorado Plateau, except perhaps in the La Sal Mountains.

Barren—Areas essentially bare of vegetation. These can include salt barrens, shale barrens, or slickrock. Plants can be present but only as scattered individuals with low cover.

Climate Zone

The climate zonation used in BLP is difficult to apply to the Colorado Plateau because it does not properly reflect the complexity of climate-controlled vegetation zonation. Two aspects of climate need to be considered, regional climate and orographic effects. For regional climate, Walter (1985) provides a useful classification with two zonobiomes in the region; subtropical–arid and arid–temperate with cold winters. Although there are latitudinal and longitudinal differences in climate on the Colorado Plateau at similar elevations, orographic effects predominate. The division of BLP zones into boreal–arctic, cold and warm temperate, and subtropical is largely controlled by elevation on the Colorado Plateau and in the southwestern United States in general. We have redrawn the climate zones as elevationally controlled zones, based largely on traditional zonation schemes. These zones are shown in Table 1 with defining and controlling factors identified. Climate zonation remains difficult to use because it can vary locally depending on aspect and topography. We have drawn zonal boundaries broadly and provide vegetation criteria (Tables 2 and 3) that help identify each zone. As climate data are scarce for much of the Colorado Plateau, no attempt is made here to provide climatic definitions and characteristics for each zone. Some zonal boundaries remain poorly understood (e.g., the montane–subalpine boundary). Also, riparian vegetation, because it consists of linear strips cutting across zones, will be more difficult to place into zones than most other kinds of vegetation. Future work addressing these problems, and also in providing a climatic characterization for each zone, is needed.

We recognize that vegetation is rarely found as discrete elevational bands on the Colorado Plateau. An alternative system could be envisioned in which landscape elements (based on topography, elevation, soils, etc.) are the building blocks of a vegetation classification. Such a system, however, would be far more difficult to use because of its increased complexity. Climate–elevation zones, although less realistic, provide a necessary tradeoff between accuracy of vegetation classification and practicality.

Biome

Many definitions of biomes exist, but a standard is "a grouping of terrestrial ecosystems on a given continent that are similar in vegetation structure or physi-

Table 1. Elevational limits and controlling factors of climate–elevation zones defined for the Colorado Plateau.

Zone	Elevational limits (m)	Controlling factors
Alpine	Upper: 3,862	Highest point on plateau
	Lower: 3,440–3,600	Snowpack, cold air drainage
Subalpine	Upper: 3,440–3,600	50° C July isotherm, wind
	Lower: 2,750–3,050	Fire?
Montane	Upper: 2,700–3,100	Winter snow, temperature?
	Lower: 1,900–2,700	Drought (arid–humid boundary)
Cold–Temperate lowland	Upper: 1,900–2,200	Competition, winter temperatures
	Lower: 900–1,200	Summer temperatures, drought
Warm–Temperate lowland	Upper: 900–1,500	Winter temperatures

Table 2. Characteristic vegetation features and species on upland or dry sites for each climate–elevation zone on the Colorado Plateau.

Zone	Vegetation	Characteristic species
Alpine	Meadows	*Geum rossii*
	Fell-field	*Erigeron vagus*
		Silene acaulis
Subalpine	Coniferous forest	*Abies lasiocarpa*[a]
		Picea engelmannii
Montane	Coniferous forest	*Abies concolor*
	Montane scrub	*Pinus ponderosa*
		Pseudotsuga menziesii
		Acer grandidentatum
		Artemisia nova
		Cercocarpus ledifolius
		Juniperus scopulorum
		Quercus gambelii
Cold–Temperate lowland	Pinyon–Juniper woodland	*Juniperus osteosperma*
	Semiarid shrub land	*Pinus edulis*
	Galleta–three awn steppe	*Atriplex confertifolia*
		Atriplex corrugata
		Coleogyne ramosissima
		Hilaria jamesii
		Stipa comata
		Stipa hymenoides
Warm–Temperate lowland[b]	Desert scrub	*Acacia greggii*
		Encelia farinosa
		Ferrocactus sp.
		Fouquieria splendens
		Larrea divaricata
		Yucca brevifolia

[a]*Abies bifolia* in Flora of North America Editorial Committee 1993.
[b]This zone is not present on the Colorado Plateau per se. Some component species, however, do exist in closely adjacent areas, such as in extreme western Grand Canyon National Park, and penetrate some distance (Havasu Creek) into the plateau along the Colorado River corridor.

ognomy, in the major features of environment to which this structure is a response, and in some characteristics of their animal communities" (Whittaker 1975:135). Whittaker's list of North American biomes is instructive; broad-leaved deciduous forest, grassland, tundra, coniferous forest, etc. Clearly, these are close to the definition of the formation in the BLP system, differing largely by including animals in the biome and by incorporating some geographic restrictions and associated climate (e.g., temperate). In the BLP system, the biome seems to be

Table 3. Characteristic vegetation features and species in wetland sites for each zone on the Colorado Plateau.

Zone	Vegetation	Characteristic species
Alpine	No data available	No data available
Subalpine	Fen, carr[a]	*Salix glauca*
Montane	Marshland	*Populus angustifolia*
	Riparian forest and scrub	*Alnus tenuifolia*
	Aspen	*Cornus sericea*
		Salix boothii
		Salix geyeriana
Cold–Temperate lowland	Marshland	*Acer negundo*
	Riparian forest and scrub	*Populus fremontii*
	Hanging garden	*Salix exigua*
		Cirsium rydbergii
		Mimulus eastwoodiae
		Primula specuicola
Warm–Temperate lowland	Mesquite bosque	*Prosopis glandulosa*
	Riparian forest and scrub	*Baccharis sarothroides*
		Fraxinus pennsylvanica
		Juglans major
		Platanus wrightii

[a]Low-lying wetland willow complexes at high (2,500 m) elevations.

more narrowly defined (compare *Rocky Mountain subalpine conifer forest* [BLP] with *temperate evergreen forest* [Whittaker]).

The last 30 years of paleoecological research (Betancourt et al. 1990) in the southwest has completely invalidated the Clements–Weaver biome concept (i.e., a coevolved vegetation unit with a center of origin migrating in unison). Because of the problems with definition of the biome and the unfortunate connotations of the name itself, we have completely revised this level. Rather than use the biome concept, we use floristic provinces. We are impressed by the statistically robust and intensive floristic analyses of McLaughlin (1986, 1989, 1992). Our classification uses his subprovinces (but names them provinces for convenience). McLaughlin recognized a distinct Colorado Plateau unit, which he named the Colorado Plateau subprovince of the Intermountain Province. The province level in our new classification logically follows biogeographic realm in the hierarchy, so it is placed second. We prefer to use McLaughlin' subprovinces rather than provinces because the former are more likely to conform to climatic, physiographic, or geological classifications in use in the west (Hunt 1967). Also, any extensions of McLaughlin's system to other parts of North

America could produce changes in the higher levels in his hierarchy. His subprovinces comprise one of the fundamental building blocks of his system and should remain unaffected by more extensive analysis.

Series

Series is a widely used term throughout the western United States, as used by the U.S. Forest Service in their extensive vegetation classifications. A series is defined and named by the dominant species in a community, or codominant species if more than one is present. Currently, no set of rules has been formulated for defining a series. We incorporated published series from a wide variety of sources into our classification.

Association

Associations have traditionally been difficult to define, and we do not attempt to provide a definition here. A consistent method of naming them is available, however (e.g., U.S. Forest Service). The name is based on the dominants in all recognizable important strata. For example, under ponderosa pine series are the following associations (community-habitat types sensu U.S. Forest Service): *Pinus ponderosa–Muhlenbergia virescens*, *P. ponderosa–Festuca arizonica*, *P. ponderosa–Arctostaphylos pungens*, etc. (Hanks et al. 1983). Although the emphasis on classifying Colorado Plateau vegetation is not on the association, this method of recognizing and naming associations is probably the best system to use to prevent confusion with other work and to be consistent with classifications of the U.S. Forest Service.

Spence–Romme–Floyd-Hanna–Rowlands Classification

The classification presented here differs in several respects from the BLP classification, although they share strong philosophical and logical similarities. We believe that it is inappropriate to continue to use the BLP name, and have used the first letters of our surnames (Spence, Romme, Floyd-Hanna, and Rowlands; SRFR) to name the new classification.

The hierarchical structure of the SRFR system follows. Each letter in the series ABCDEF.GHIJ is associated with one of the six levels in the hierarchy:

A	=	Biogeographic realm (1 for Nearctic realm; not shown in classification)
BC	=	Floristic province (first number in sequence is 01 because more than 10 provinces exist)
D	=	Climate–elevation zone
EF	=	Plant formation
GH	=	Series (first two numbers to the right of decimal)
IJ	=	Association

In actual named vegetation, the letters are replaced by numbers, hence the sequence 101201.01 represents the *Picea engelmannii–Abies lasiocarpa* series in the subalpine zone, forest and woodland formation, on the Colorado Plateau Province in the Nearctic realm (no association is indicated).

A preliminary classification of the Colorado Plateau to the series level is presented in Table 4. This listing highlights the many gaps in our knowledge of the vegetation on the Colorado Plateau. In particular, high-elevation, treeless vegetation and wetlands are poorly understood.

How to Identify Vegetation

Once vegetation data are collected and analyzed (Rowlands 1994), a series level determination can usually be made. The dominant or codominants (i.e., two or more dominants) are used to define the series. Placement of the series into the classification is usually routine after this stage. Three questions need to be answered.

1. What is the floristic province?

Some problems may arise if the site in question is on a province boundary. The best solution is to determine the floristic affinities of the subdominant herbaceous flora—dominant plant species, especially woody species, tend to be widespread and often do not conform to floristic provinces—and whether the area is considered geological or physiographical.

2. In which climate–elevation zone does the vegetation exist?

Because climatic zonation is highly variable from area to area, problems will be encountered in making a decision. We attempted to provide boundaries that relate to biologically important limits, such as treeline, the arid–humid boundary, frost-free climates, etc. Many plant species, particularly the dominants, are limited in distribution by some aspect of climate. Many subdominant species of flora (as well as fauna) will also conform to the limits defined by the

Table 4. Preliminary Spence–Romme–Floyd-Hanna–Rowlands (SRFR) vegetation classification for the Colorado Plateau.[a]

01 Colorado Plateau Province (0 not listed below)		
	11 Alpine zone (3,440 m)	
1101 Grassland formation		
	1101.01	*Carex elynoides* series
	1101.02	*Festuca ovina* series
	1101.03	
1102 Forb land formation		
	1102.01	*Erigeron vagus* series
	1102.02	*Geum rossii* series
	1102.03	
1103 Low-shrub land formation		
	1103.01	
1104 Marshland formation		
	1104.01	
1105 Aquatic formation		
	1105.01	
1106 Barren formation		
	12 Subalpine zone (2,750–3,600 m)	
1201 Forest and woodland formation		
	1201.01	*Picea engelmannii–Abies lasiocarpa* series
	1201.02	*Picea engelmannii* series
	1201.03	*Abies lasiocarpa* series
	1201.04	*Populus tremuloides* series
	1201.05	*Pinus longaeva* series
	1201.06	
1202 Tall-shrub land formation		
	1202.01	
1203 Low-shrub land formation		
	1203.01	*Juniperus communis* series
	1203.02	*Ribes montigenum* series
	1203.03	*Potentilla fruticosa* series
	1203.04	*Salix wolfii* series
	1203.05	
1204 Grassland formation		
	1204.01	*Festuca ovina* series
	1204.02	*Festuca thurberi* series
	1204.03	
1205 Marshland formation		
	1205.01	
1206 Forb land formation		
	1206.01	
1207 Aquatic formation		
	1207.01	
1208 Barren formation		
	1208.01	

Table 4. *Continued.*

01 Colorado Plateau Province (0 not listed below)		
	13 Montane zone (1,900–3,100 m)	
1301 Forest and woodland formation		
	1301.01	*Pseudotsuga menziesii* series
	1301.02	*Abies concolor* series
	1301.03	*Pinus ponderosa* series
	1301.04	*Pinus flexilis* series
	1301.05	*Populus tremuloides* series
	1301.06	*Juniperus scopulorum* series
	1301.07	*Picea pungens* series
	1301.08	*Acer grandidentatum* series
	1301.09	
1302 Tall-shrub land formation		
	1302.01	*Cercocarpus ledifolius* series
	1302.02	*Quercus gambelii* series
	1302.03	*Amelanchier utahensis* series
	1302.04	*Robinia neomexicana* series
	1302.05	*Chrysothamnus nauseosus* series
	1302.06	*Betula occidentalis* series
	1302.07	*Alnus tenuifolia* series
	1302.08	*Cornus stolonifera* series
	1302.09	*Salix boothii* series
	1302.10	*Salix bebbiana* series
	1302.11	
1303 Low-shrub land formation		
	1303.01	*Artemisia nova* series
	1303.02	*Purshia tridentata* series
	1303.03	*Arctostaphylos patula* series
	1303.04	
1304 Grassland formation		
	1304.01	*Poa fendleriana* series
	1304.02	
1305 Marshland formation		
	1305.01	*Eleocharis palustris* series
	1305.02	
1306 Forb land formation		
	1306.01	*Pteridium aquilinum* series
	1306.02	*Eriogonum panguicense* series
	1306.03	
1307 Aquatic formation		
	1307.01	
1308 Barren formation		
	14 Cold–Temperate lowland zone (900–2,200 m)	
1401 Forest and woodland formation		
	1401.01	*Pinus edulis* series
	1401.02	*Juniperus osteosperma* series
	1401.03	*Juniperus monosperma* series

Table 4. *Continued.*

01 Colorado Plateau Province (0 not listed below)	
1401.04	*Populus angustifolia* series
1401.05	*Populus fremontii* series
1401.06	*Salix goodingii* series
1401.07	*Acer negundo* series
1401.08	*Elaeagnus angustifolia* series
1401.09	*Ostrya knowltonii* series
1401.10	*Rhamnus betulifolia* series
1401.11	*Pinus edulis–Juniperus osteosperma* series
1401.12	
1402 Tall-shrub land formation	
1402.01	*Artemisia tridentata* series
1402.02	*Quercus gambelii* series
1402.03	*Sarcobatus vermiculatus* series
1402.04	*Tamarix ramosissima* series
1402.05	*Salix exigua* series
1402.06	*Amelanchier utahensis* series
1402.07	*Salix lutea* series
1402.08	*Salix goodingii* series
1402.09	*Atriplex canescens* series
1402.10	*Cerotoides lanata* series
1402.11	
1403 Low-shrub land formation	
1403.01	*Coleogyne ramosissima* series
1403.02	*Artemisia spinescens* series
1403.03	*Artemisia pygmaea* series
1403.04	*Artemisia filifolia* series
1403.05	*Grayia spinosa* series
1403.06	*Atriplex confertifolia* series
1403.07	*Zuckia brandegei* series
1403.08	*Atriplex corrugata* series
1403.09	*Atriplex gardneri* series
1403.10	*Ephedra viridis* series
1403.11	*Ephedra cutleri* series
1403.12	*Poliomintha incana* series
1403.13	*Gutierrezia sarothrae* series
1403.14	*Vanclevea stylosa* series
1403.15	*Eriogonum corymbosum* series
1403.16	*Fallugia paradoxa* series
1403.17	*Quercus harvardii-undulata* series
1403.18	*Parryella filifolia* series
1403.19	*Toxicodendron rydbergii* series
1403.20	
1404 Grassland formation	
1404.01	*Hilaria jamesii–Aristida purpurea* series
1404.02	*Stipa hymenoides* series
1404.03	*Stipa comata* series

Table 4. *Continued.*

01 Colorado Plateau Province (0 not listed below)	
1404.04	*Hilaria jamesii* series
1404.05	*Bouteloua gracilis* series
1404.06	*Sporobolus cryptandrus–Sporobolus contractus* series
1404.07	*Sporobolus airoides* series
1404.08	*Bromus tectorum* series
1404.09	*Distichlis spicata* series
1404.10	*Elymus salinus* series
1404.11	*Calamovilfa gigantea* series
1404.12	*Phragmites australis* series
1404.13	*Panicum virgatum* series
1404.14	
1405 Marshland formation	
1405.01	*Typha latifolia* series
1405.02	*Typha domingensis* series
1405.03	*Scirpus pungens* series
1405.04	*Scirpus validus* series
1405.05	*Scirpus acutus* series
1405.06	*Juncus arcticus* series
1405.07	*Eleocharis palustris* series
1405.08	*Cyperus erythrorhizos* series
1405.09	*Carex nebrascensis* series
1405.10	*Juncus arcticus–Equisetum hyemale* series
1405.11	
1406 Forb land formation	
1406.01	*Adiantum capillus-veneris* series
1406.02	*Platyschkuhria integrifolia–Cleome palmeriana* series
1406.03	*Eriogonum flexum* series
1406.04	*Eriogonum inflatum* series
1406.05	*Salsola australis* series
1406.06	*Melilotus officinalis* series
1406.07	*Solidago occidentalis* series
1406.08	*Oxytenia acerosa* series
1406.09	*Solidago canadensis* series
1406.10	
1407 Aquatic formation	
1407.01	*Zanichellia palustris* series
1407.02	
1408 Barren formation	

[a]Numbers without designated series are available for the incorporation of new series.

dominant species. This observation forms the basis for life zone classifications such as that of C. H. Merriam. Information helpful in determining the proper climate–elevation zone can be found in Tables 1, 2, and 3. Zonal boundaries are broadly drawn to reflect real differences in climate, available flora, and history in different parts of the Colorado Plateau.

3. To which plant formation does the series belong?

Generally this is easy to do, but certain exceptions do exist on the Colorado Plateau. Mixed shrub–grass vegetation, traditionally called shrub–steppe in the United States, may be difficult to place. If shrubs dominate in terms of cover and biomass, the series can be classified as a shrub land. If shrubs are less common than the grasses, however, the best placement is grassland. When the mix seems to be even, a new formation, shrub–steppe, may be needed.

Discussion

We have defined the vegetational Colorado Plateau as those areas on the geologic–physiographic Colorado Plateau above the elevation of the hot desert flora as defined principally by the presence of creosote bush, *Larrea divaricata*, although other species could be named (Tables 2 and 3). Along the southwestern and southern edges, this elevation varies from 900 to 1,500 m. Boundaries elsewhere are more difficult to determine. To the west and northwest, the western slope of the High Plateau section of the Colorado Plateau grades into the Great Basin. The high Uinta Mountains define the northern edge. The eastern and southeastern edges form an indefinite and complex boundary with the central and southern Rocky Mountains. The White Mountains and Mogollon Rim form the boundary between the Colorado Plateau and the Madrean and Sonoran regions to the south. Classification of vegetation into surrounding McLaughlin subprovinces (provinces in SRFR), including the Great Basin, central Rocky Mountains, southern Rocky Mountains, Madrean, and Sonoran, may be more appropriate depending on where the vegetation work is being accomplished.

Because the classification of the region into floristic groups is relatively new, little work has been done on delimiting floristic province boundaries. We believe the work of McLaughlin (1992) could provide a useful starting point for fruitful research into the nature of floristic boundaries and the evolution and dispersal of floristic elements. We emphasize that the floristic Colorado Plateau

is not the same as a Colorado Plateau floristic element. The former is defined by boundaries, albeit not well understood yet; the latter consists of species that presumably originated on the plateau but in many instances extend into surrounding provinces (McLaughlin 1986, 1989). Furthermore, provinces can be fragmented, with more or less intact outlier regions embedded within other provinces. McLaughlin (1992) illustrates this with his central Rocky Mountain subprovince, which includes a large disjunct fragment in northeastern Nevada surrounded by McLaughlin's Great Basin subprovince. On the Colorado Plateau, a likely candidate for disjunction is the La Sal Mountains, which harbor at higher elevations a large number of species characteristic of the central Rocky Mountains.

The problem of disjuncts also exists at the climate–elevation level in the classification. Relict patches of vegetation exist on the Colorado Plateau well below or above their usual elevational limits. For example, patches of Douglas-fir (*Pseudotsuga menziesii*) are present at elevations as low as 1,500 m, well within the cold–temperate lowland zone. Vegetationally, these patches are related in composition to higher-elevation montane forests. Although not yet investigated, it is probable that these patches are present in microclimates that mimic climates at higher elevations. We suggest that classification of relict communities like these should reflect their origins. In the instance of the Douglas-fir relicts, we would classify them as montane rather than cold–temperate lowland communities.

Because the classification name (e.g., series, formation names) does not necessarily convey all information about the vegetation, we suggest a series of descriptors that could provide additional information. First, we recommend adding data on the Raunkiaer life-form system (Raunkiaer 1934) for the species in the vegetation classification (shown in Table 5). This system provides information on the functional responses of plant species to climate and has been widely used throughout the world. For example, the *Pinus ponderosa* series (Table 4, 1301.03) is dominated by megaphanerophytes (Pg) and mesophanerophytes (Pm), whereas the *Artemisia tridentata* series (1402.01) is dominated by nanophanerophytes (Pn) and hemicryptophytes (H). Combined with data on leaf duration and size (for at least the dominants), vegetation cover, landforms, soils, and other physical data, a much clearer picture of the vegetation in question can be obtained.

Several aspects of vegetation classification will need to be addressed in the future. First, a standardized list of the flora with identification keys needs to

Table 5. Suggested Raunkiaer life form classification (Raunkiaer 1934) for use with the SRFR vegetation classification.[a]

Life form	Code[b]	Characteristics
		Vascular plants
Megaphanerophytes	Pg	Buds 25 m, large trees
Mesophanerophyte	Pm	Buds 10–25 m, trees
Microphanerophyte	Pp	Buds 2–10 m, trees, tall shrubs
Nanophanerophyte	Pn	Buds 0.5–2 m, shrubs
Chamaephyte	Ch	Buds 0–0.5 m, dwarf shrubs
Hemicryptophyte	H	Buds at ground level, forbs, graminoids
Geophyte	G	Buds buried, bulb forbs
Therophyte	Th	Annuals
Stem succulent[c]	SS	Cacti
Liana	Li	Supported by other plants, rooted in ground
Epiphyte	E	On other plants, not rooted in ground
Parasite	Pa	Parasitic or saprophytic on other plants
Hydrophyte	HH	Structures supported by water
		Nonvascular plants[d]
Lichens	L	Lichens (composite alga–fungus)
Bryophyte	Br	Mosses, liverworts, hornworts
Algae	Al	Mostly aquatic, includes *Chara*

[a]Raunkiaer's classification sytem is based on the position of the regenerative parts (perrenating buds) relative to the substrate.
[b]With some modification, the codes are based on Dansereau (1957).
[c]Leaf succulents are included as either chamaephytes or hemicryptophytes by some authors (Mueller-Dombois and Ellenberg 1974).
[d]Nonvascular plants are generally classified into one or more of the above categories as specialized members. For example, Mueller-Dombois and Ellenberg (1974) classify foliose lichens as thallo-hemicryptophytes using the abbreviation Li H fol. For our classification we recommend a simpler system using L, Br, and Al. The interested reader looking for a more intensive life-form classification system should consult Mueller-Dombois and Ellenberg (1974).

be developed for the Colorado Plateau. Second, objective ways of classifying complex vegetation data at the series and association levels needs to be implemented. We recommend the use of relatively objective multivariate classification and ordination techniques (Causton 1988) for vegetation classification work at or below the series level. Such techniques are readily available as commercial software and take the form of either divisive; polythetic (e.g., TWINSPAN, developed by Hill 1979); or various agglomerative, polythetic methods (e.g. the several forms of cluster analysis described in Pielou 1984). Finally, until research on floristic boundaries is completed, a set of rough guidelines based on characteristic vegetation series or floristic criteria will need

to be developed so these boundaries can be determined for classification of vegetation.

The SRFR classification should be adaptable to any floristic region in North America, although it may not work at all levels in tropical vegetation (series level classifications are difficult and often impossible to use in the species-rich tropics). Although McLaughlin analyzed the flora of only the western United States, his techniques and philosophy may be extended to other parts of the country. Currently, enough vegetation work has been done in the United States and Canada to formulate climate–elevation zonation for most areas. As our classification is open-ended and flexible, it can be modified to fit most situations that we can foresee elsewhere in North America. Currently, we are adapting the SRFR classification to the central Rocky Mountain region and the Sonoran Desert.

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[2]Asterisk indicates unpublished material.

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